NRL Memorandum Report 1378

THE PERFORMANCE OF LEAD-SILVER ANODES IN CATHODIC PROTECTION OF RESERVE FLEET VESSELS AT THE SAN DIEGO GROUP, PACIFIC RESERVE FLEET

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ABSTRACT

This report summarizes the performance of lead-2% silver rod used as impressed current anodes at the San Diego Group, Pacific Reserve Fleet between 10 April 1961 and 25 October 1962 or for approximately 18-1/2 months.

It was found that 1/2-inch diameter anodes - 6 feet in length could replace conventional 3-inch diameter by 5 feet long graphite anodes with considerable economy. After 18-1/2 months, the actual deterioration of the anodes was so slight as to lead us to believe that they will have a life of many times that covered in these evaluations provided they are properly installed and maintained. One-half inch diameter rod is the minimum size rod that can be used; smaller rod has insufficient rigidity to prevent flexing in service. Wherever flexing occures, flaking of the protective coating formed in service follows accompanied by a reduction in the diameter of the rod to form a new coating. Very poor performance was obtained where the lead-silver anodes were in the mud. Satisfactory joints between the anode and lead wires were developed. These were made by using either commercial connectors or by a method of peening the copper-lead wires into a drilled hole in the anode. Either type of joint was then covered with a vinyl mastic and sealed with vinyl tape. Excessive deterioration of the anode occurred where rubber friction tape was used in place of the vinyl tape.

PROBLEM STATUS

This is an interim report. Work on this problem is continuing.

AUTHORIZATION

NRL PROBLEM NUMBER: M04-02

BUREAU PROBLEM NUMBERS: SR 007-08-07, Task 1203
(SF 013-05-07, Task 2759)
RR 007-08-44-5510

INTRODUCTION

Hitherto, graphite anodes 3-in. in diameter x 60-inches long have been used exclusively in impressed cathodic protection installations for Reserve Fleet vessels. At the San Diego Group of the Pacific Reserve Fleet, the loss of graphite anodes from mechanical damage has been an item of considerable magnitude in the maintenance costs for these systems, and puts an additional burden on the few personnel available to maintain the systems. So many anodes were being lost at the San Diego Group that they employed divers to recover them.

The recent introduction of lead-2% silver for use as impressed current anodes prompted Code 633P of the Bureau of Ships to request that NRL set up a field evaluation test to determine the suitability of these anodes for Reserve Fleet use and the desirability of substituting them for the graphite anodes. Details for this work were covered in references (a), (b), (c) and (d).

The Naval Research Laboratory furnished one-half and one-quarter inch diameter lead-2% silver rod for these anodes, developed methods for attaching them to electrical lead wires, furnished ampere-hour meters for monitoring the current and supervised the installations.

Personnel of the San Diego Group made the installations, monitored the systems, and prepared weekly reports for NRL on the condition of the anodes, currents used, and potentials of the vessels. This information has been summarized in this report.

The test was started on 10 April 1961, inspected by NRL personnel in December 1961, and terminated on 25 October 1962 after 563 days.

INSTALLATION DETAILS

(a) Six-foot lengths of one-half inch diameter rod were installed on the U.S.S. JOYCE (DER-317). Four anodes were used and suspended both fore and aft on both sides of the vessel at frames 30-45 and 100-130. Attachment of the lead wires was made by either using a commercially furnished connector and crimping both the lead wire and anode into the unit with a crimping tool by a method developed by the Materials Laboratory of the New York Naval Shipyard, reference (e) or by inserting the bare wire into

a drilled hole in the anode and then tightening this joint by vigorous peening. Both types of joint were then covered with a vinyl filler and topped with vinyl electrical tape to produce a watertight joint. Measurements made with a clamp-on ammeter indicated an even distribution in current to all anodes.

(b) Ten-foot lengths of one-quarter inch diameter rod were installed on the U.S.S. HOWARD (DE-346). Six anodes were suspended both fore and aft on both sides of the vessel at frames 20-52, 120-130, and midship. Attachment of the lead wire and anode rod was made by inserting both of them in a short length of copper tubing and peening the unit with a chisel and hammer. This joint was protected in a similar manner as the one-half inch anode. Equal current to each anode was indicated by the clamp-on ammeter.

(c) Thirty-foot lengths of one-quarter inch diameter rod was installed on the U.S.S. BARNES (DE-353). One anode was suspended by a long lead wire from the stern, and the other from the bow on opposite sides of the vessel. These anodes laid in the mud parallel with the keel. Splices were made similar to that described under (b).

(d) One-inch diameter x 24-inch length graphite anodes were suspended by No. 12 plastic insulated electrical wire at aft, midship, and forward locations on each side of the U.S.S. HODGES (DE-231). A solderless connector fitted into one end of the lead wire and this was secured to the anode by a small brass screw secured in a tapped hole in the anode. This joint was made waterproof by an epoxy cap.

All anodes were examined in the field during December 1961 and October 1962 and typical ones returned to the NRL for critical inspection. They represented anodes performing for approximately 9, 10, and 19 months.

PERFORMANCE OF THE VARIOUS ANODES

(a) One-half inch diameter lead-silver rod. Three of these 6-foot long anodes were examined after various periods of service. The first, Figure 1, was removed on 21 December 1961 after 255 days of service during which it had passed 26,000 ampere-hours of current for an average of nearly 5 amperes (7 amps/sq. ft.). The lead wire splice has been uncovered in this photograph to show the details of the joint, which was in excellent condition. Flexing of the anode in service has

caused the coating to peel off in spots with slight reduction in the diameter. The minimum diameter of the rod at any of these areas was approximately 7/16 inch. The brittleness of the coating is evidenced by its flaking where the anode was bent after removal from service. Figure 2 is a cross-section view of location "E" of Figure 1 and shows the coating which was estimated to be 15-20 mills thick.

The second anode, whose surface appearance is shown in Figure 3, was installed 21 December 1961 and removed 25 October 1962 after 308 days of service. During this time it had passed 79,800 ampere-hours of current for an average of nearly 11 amperes (14 amps/sq. ft.). The coating was estimated to be approximately 1/16 inch thick and very brittle. It had broken at various locations along the length of the rod from flexing during inspection. The minimum diameter of the rod at these locations was approximately 7/16 inch except at just outside the splice where the metal had necked down to 1/4 inch. However, this splice was different from the others in that the Group used electrical friction tape which apparently disintegrated.

The third anode, areas of which are shown in Figure 4, was removed on 25 October 1962 after 563 days of service. 106,400 ampere-hours of current flowed from this anode for an average of 8 amperes (10 amps/sq. ft.). Like the other two anodes, the coating on this anode had also flaked from flexing and had been reformed at various areas. The coating was approximately 1/16 inch thick. The minimum diameter of metal at the flaked areas was found to be 3/8 inch. The good condition of the splice and vinyl tape after 18 months' service is illustrated in the figure.

(b) One-fourth inch diameter rod - 10 ft. long. A section of this anode was removed on 21 December 1961 after approximately 255 days, during which 7,500 ampere-hours of current had passed for an average of slightly more than 1 ampere (1 1/2 amps/sq. ft.). A considerable amount of the coating had flaked off and the diameter of the remaining metal at these areas was approximately 1/8 inch. This condition is illustrated in Figure 5. This diameter of rod has insufficient rigidity to prevent flaking of the brittle coating from even slight handling and movement in the water. All anodes of this diameter continued to deteriorate and were lost and replaced after approximately one year of service.

(c) One-fourth inch diameter rod - 30 ft. long. These anodes were never pulled up for examination since the non-rigid character of such lengths would have caused premature failure from flaking of the coating. On 14 November 1961, after approxi-

mately 218 days of service, both anodes were missing. Examination of the lead wires indicated that the metal had corroded to such an extent just outside the splice to cause severing at this point. Apparently, the attack on these anodes in the mud was much greater than that which occurred on the other types of anodes that were out of the mud. It is estimated that 4-5 amperes of current were used on each anode. This corresponds to a current density of approximately 2-1/2 amps/sq. ft.

(d) One-inch diameter graphite anodes - 2 ft long. On 1 July 1961, after 82 days of service, the Group reported that these anodes had deteriorated to approximately 1/2-inch diameter. On 21 December 1961, their cross section had reduced to such an extent that they were considered to have ended their useful life and the test with them was discontinued. They thus served for 8-9 months with a current of 1-2 amperes per anode.

SUMMARY AND CONCLUSIONS

1. Performance of one-half and one-quarter inch lead - 2% silver anodes for impressed current cathodic protection systems on selected vessels of the San Diego Reserve Fleet Group has been evaluated and is summarized in this report for the period 10 April 1961 - 25 October 1962.

2. The lead-silver anodes gave exceptionally good performance in these tests where certain precautions were observed in their installation.

3. The rod from which these anodes are assembled should have a minimum diameter of one-half inch. Less thick anodes have insufficient rigidity to prevent flexing of the material with resultant flaking of the protective coatings formed in service. Should this coating be flaked off, the diameter of the rod will be reduced by the formation of a new coating.

4. Under the conditions of exposure in these tests, the lead-silver anodes must be kept out of the mud to give efficient performance.

5. Lead-silver anodes can be substituted for conventional graphite anodes for use in seawater with considerable economy in maintenance costs, provided proper precautions are observed in their installation.

6. Satisfactory attachments of anodes and lead wire can be obtained from the use of either commercial connectors or by a special peening procedure developed in this work. Waterproof and protective joints can be made by using a vinyl filler and vinyl electrical tape.

7. The deterioration of the lead-silver anodes was found to be less than that of the 1" x 24" graphite anodes.

8. The electrolytic resistance of the 1/2" x 72" lead-silver anode was about the same as for the 3" x 60" graphite so that present rectifiers and electrical circuits can be used interchangeably.

9. While it would be desirable to increase the stiffness of the lead-silver anodes to prevent flexing and flaking of the protective coating by either adding antimony (up to 5%) or using a stiff metallic core, the added performance might not justify the additional costs incurred.

ACKNOWLEDGEMENTS

This work could not have been conducted except through the cooperation of personnel of the San Diego Group, Pacific Reserve Fleet. This is gratefully acknowledged.

REFERENCES

(a) BUSHIPS ltr, Ser 633P-2427 of 26 Oct 1960.
(b) BUSHIPS ltr, Ser 633P-3118 of 27 Dec 1960.
(c) PACRESFLT SPEEDLTR, Ser 634/85 of 10 Jan 1961.
(d) SAN DIEGO GROUP ltr, Ser 60/96 of 20 Jan 1961.
(e) NEW YORK NAVAL SHIPYARD ltr, LAB PROJECT 5589-1 of 8 Dec 1960.

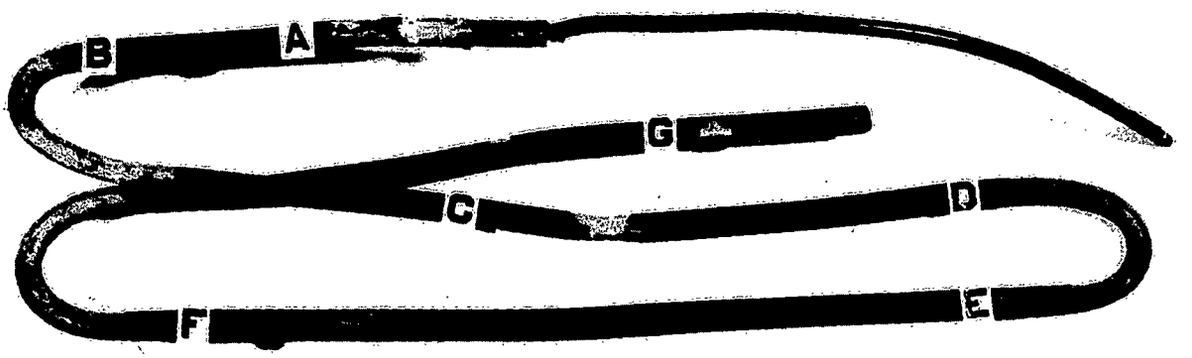


Fig. 1 - View of six-foot length of 1/2-inch diameter lead-silver anode after 255 days of service. x 1/2

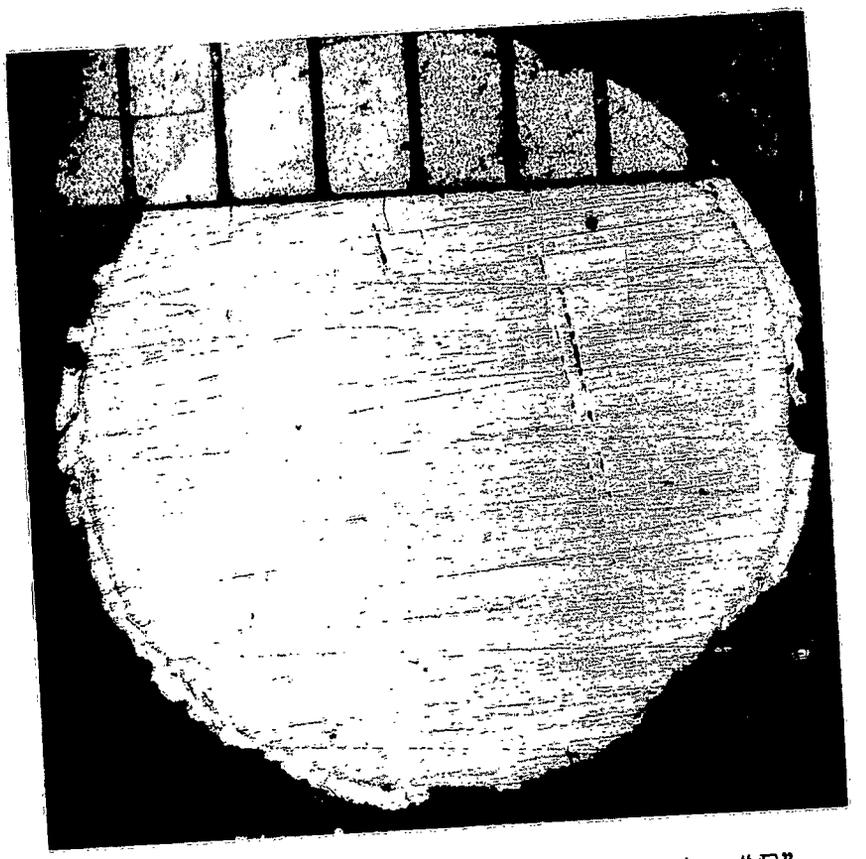
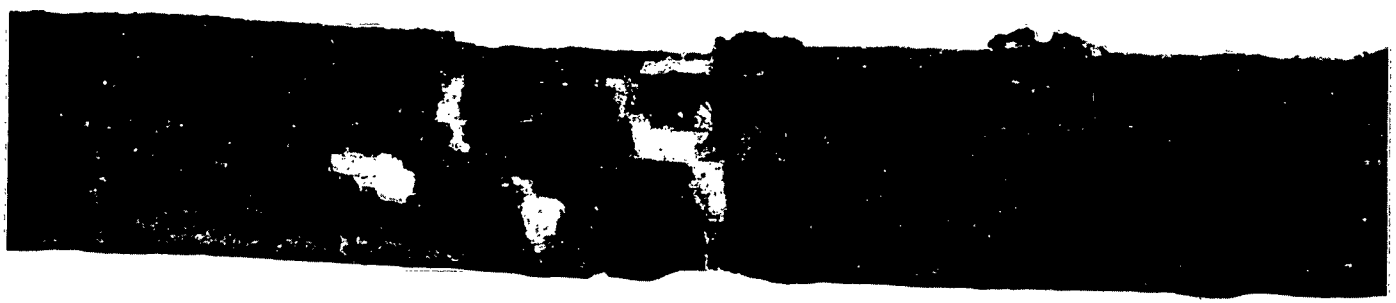


Fig. 2 - Cross-sectional view of location "E" of Fig. 1. x8 Each division of the scale - 1/16-inch.

(a) lead splice



(b) area where coating had flaked

Fig. 3 - Appearance of lead-silver anode after 308 days of service. x 1-1/2

(a) lead splice

(b) area where coating had flaked

Fig. 4 - Appearance of lead-silver anode after 563 days of service. x 1-1/2

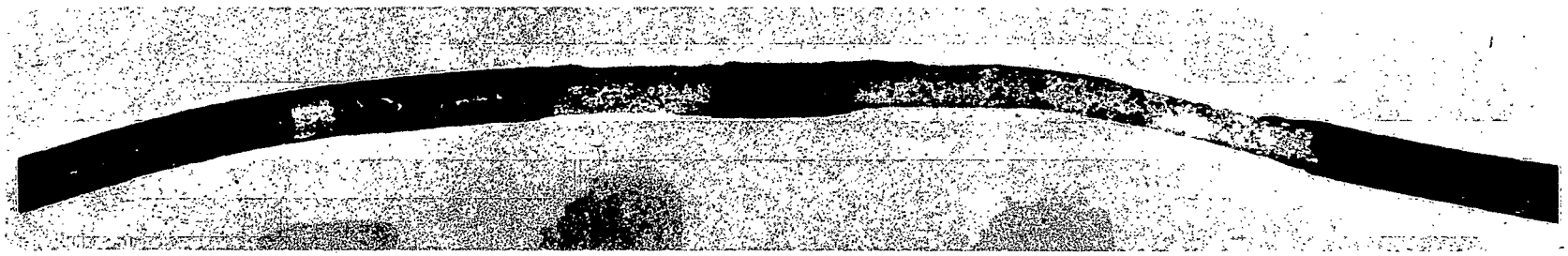


Fig. 5 - Section of 1/4-inch lead-silver anode removed after 255 days service. x 1-1/4

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